Patellar Forces And Torsions Resulting From Decreased Activation of the Vastus Medialis Muscle

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INTRODUCTION

The quadriceps is a powerful muscle group that plays a significant role in many activities of daily living and sports. This group of muscles produces movement at both the hip and knee joint. The knee is a complex joint that must withstand a great deal of stress. The amount of stress placed on the knee puts the joint at risk of injury, dysfunctional movement, and pain.

Patellofemoral pain, also known as anterior knee pain, is one of the most frequent knee conditions seen by sports medicine providers [1]. Dysfunctional tracking of the patella is thought to be a possible cause of such knee pain. There is controversy related to whether or not weakness in the vastus medialis portion of the quadriceps muscle plays a critical role in patellar tracking. It is thought that weakness in the vastus medialis will cause the patella to track abnormally.

It has been shown that asymmetric quadriceps loading leads to an alteration in the mediolateral forces [2] or moments. The purpose of this project was to determine if reduced maximal strength of the vastus medialis will cause optimized muscle forces in a musculoskeletal model to increase laterally directed patellar forces or patellar torsion.

METHODS

- Eight adults (4 males, age: 34.75±13.15 yr, body mass: 71.02±9.80 kg, height: 1.81±0.06 m and 4 females, age: 21.75±0.5 yr, body mass: 64.84±11.67 kg, height: 1.65±0.09 m) with no lower limb injuries volunteered to participate
- 17 reflective markers were attached to each participant to identify anatomical landmarks (Figure 1)
- Five maximum effort jumps and landings were collected while motion and ground reaction forces were recorded
- Kinematics were recorded at 200 Hz (Vicon MX, Vicon, Centennial, CO, USA) and force data at 1000 Hz (AMTI, Watertown, MA)
- Two models for each participant were constructed using Mat Lab
  - A rigid body model was used to estimate the joint moments at the ankle, knee, and hip
  - A 44 muscle musculoskeletal model was used to estimate length and velocity adjusted maximal muscles forces and moment arms of the muscles in the lower extremity using Arnold [3], as seen in Figure 2
- Muscle forces required to produce the joint moments were estimated using optimization techniques that minimized the sum of the muscle stress squared, constrained by the moments found using the rigid body model and zero
- Moments were found in the sagittal plane at the ankle, knee and hip, as well as the ankle and hip moments in the frontal plane
- The patellar tendon force was adjusted using the quadriceps tendon to ligament force ratio [4]
- The model was then altered to reduce the maximum force producing capabilities of the vastus medialis muscle
- Reductions of 10%, 20%, 30%, 40% and 50% of the normal vastus medialis force were examined
- Peak medio-lateral forces and torsions were identified
- Paired t-tests were utilized to determine the effect of decreased vastus medialis force for each participant, with an alpha criterion of 0.05.

METHODS CONTINUED

Figure 1: Musculoskeletal model while a maximal effort jump and landing is performed

Figure 2: Musculoskeletal model while a maximal effort jump and landing is performed

RESULTS

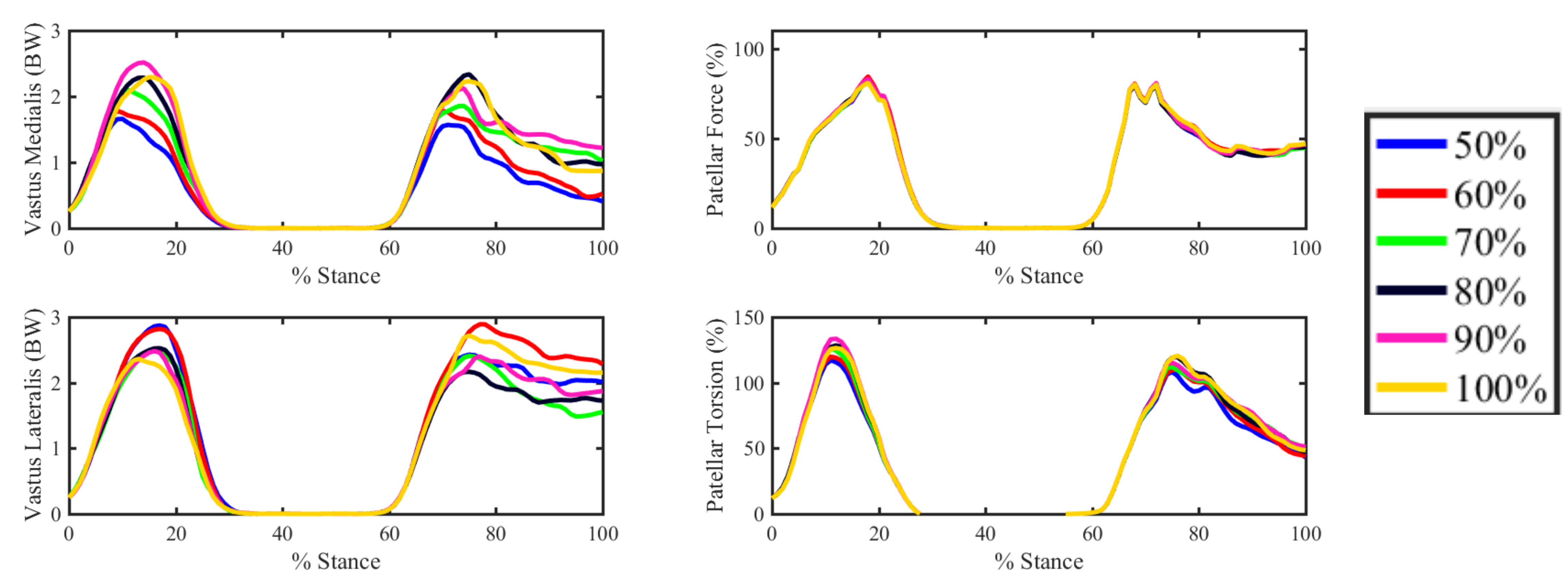

Figure 3: Peak jumping muscle forces, patellar forces, and patellar torsion during simulated reduction of vastus medialis strength.

Reduction in Vastus Medialis	Peak Vastus Medialis Force (BW)	Peak Vastus Lateralis Force(BW)	Peak Patellar Lateral Force (%)	Peak Patellar Torsion (%)
50	1.52±.30	2.59±.94	98.1±17.1	112.4±22.3
60	1.66±.32	2.51±.92	99.6±17.8	107.5±18.3
70	1.80±.36	2.36±.83	99.2±17.7	104.7±18.3
80	1.93±.46	2.30±.71	99.7±17.3	103.6±19.8
90	2.00±.46	2.24±.71	100.0±16.1	97.2±17.6
100	2.01±.49	2.28±.71	100.0±17.1	100.0±15.4

Figure 4: Jumping muscle forces and patellar loading during simulated reduction of vastus medialis strength.

RESULTS

As expected, the reduced maximum force producing capabilities of the vastus medialis decreased its estimated muscle force. In turn, this increased the vastus lateralis muscle force in order to create enough extensor torque to produce the movement (Figure 3 and 4).

Peak patellar mediolateral forces were decreased by 1.9% from the 100% condition to the 50% condition while peak patellar torsion was increased by 12.4%. Only the 50% and 60% conditions were statistically significantly different from the 100% condition in these two variables (Figure 4).

CONCLUSIONS

The musculoskeletal model with optimization of muscle forces was able to model the effects of decreased vastus medialis strength. This resulted in small decreases in laterally direct patellar forces and somewhat larger increases in patellar torsions.

It should be noted that these results are dependent on the orientation of the muscles relative to the patella. In the Arnold model, the vastus medialis, the vastus lateralis and the patellar ligament tend to pull the patella in a lateral direction. A more complex model might be necessary to fully understand the loading of the patella. It should also be noted that this technique does not allow for alterations in the kinematics or joint moments that might occur during actual weakening of the vastus medialis muscle.

ACKNOWLEDGEMENTS

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